2006 CCRTS

THE STATE OF THE ART AND THE STATE OF THE PRACTICE

Leveraging C2IEDM for Enhancing Systems Interoperability

Lessons Learnt

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Abstract

The current conduct of operations for peace keeping or disaster relief sees the increasing need for co-operation among different national agencies and nations, to collaborate and to maintain awareness of the status, capabilities, response plans and C2 resources. The urgency and scale of such missions bring forth the need for seamless transition to operation, as well as the need for better interoperability of the respective systems used among the national agencies and the coalition partners.

This paper presents the exploration conducted by Defence Science and Technology Agency (DSTA) on enhancing the integration between C2 and IT (such as, human resource and logistic) systems, as well as the interoperability between new and existing/legacy systems. In the exploration, DSTA uses *Command and Control Information Exchange Data Model* (C2IEDM) as the referential data model for building an information hub, and encapsulated the hub with a set of open-standards based web services. The set of services offered a consistent way of accessing and updating the information hub, while maintaining the hub's integrity by enforcing the business rules defined in C2IEDM. In addition, the set of services also shields web service consumers from the complexity of the model. This paper will discuss on the information integration architecture, challenges encountered and the lessons learnt during the exploration, while putting the state of the art data model into practice.

1 Introduction

Recent spate of natural disasters, such as Indian Ocean Tsunami in 2004, Hurricane Katrina in 2005 and Pakistan/Indian earthquake in 2005 are massive in scale and required large scale relief operations involving military, government agencies and Non-Government Organisations (NGOs). The urgency of such operations require resources to be pooled together quickly and moved rapidly to the affected areas while maintaining full visibility and accountability of personnel and equipment involved in the operation.

The past paradigm of having separate systems within military, NGOs and other governmental organisations storing and processing their own silos of information could no longer support the urgency and mix of resources for such an operation. The need for an integrated system of systems that have access to critical resource information residing in all these systems is immediate, so that a disaster relief team spanning across different organisations could be put in place within the shortest possible time.

In its search for a solution to meet this need, an exploration was initiated as an attempt to integrate information residing in human resource and C2 systems into a common information hub. As force management functionality matches closely to the requirement of this exploration to manage and monitor relief teams, a Force Management System (FMS) prototype was developed for prove of concept. The prototype FMS consumes the set of services that were built on top of C2IEDM and presents a complete force structure and statuses to the user. In this paper, we discuss on the exploration conducted, the challenges encountered and the lessons learnt, using FMS for illustration. In Section 2, we discuss on the usage of C2IEDM as the base model to develop an information hub for information integration. In Section 3, we discuss on usage of web services to build an interface for shielding the complexity of C2IEDM from application developers. We discuss on the FMS prototype developed for this exploration in Section 4. Lastly, we discuss on the lessons learnt and conclusion in Section 5.

2 Information Integration

Order of Battle[1] [1] (Orbat) is commonly used in C2 systems by military planners for organising different force structures to tackle different situations. Disaster relief operations have similar requirement to have an organisation structure comprising of resources from military, government agencies as well as NGOs, in order to maintain visibility and accountability of the people and equipment involved in the operation.

Information on organisation, people and equipment exists today in IT systems that are used in day to day operation, as well as C2 systems that are used for peacetime planning, training and operations. However, the challenge to inter-operate and share information among these systems is a commonly known NxN problem as illustrated in Figure 1. Essentially, the diagram shows that interfaces between stove-piped systems are

[1] Defined by US DOD and NATO as the identification, strength, command structure, and disposition of the personnel, units, and equipment of any military force.

proprietary, which require systems to build an interface to every other system that it needs to communicate with. This way of interoperability results in NxN number of interfaces required, where N is the number of systems in the network.

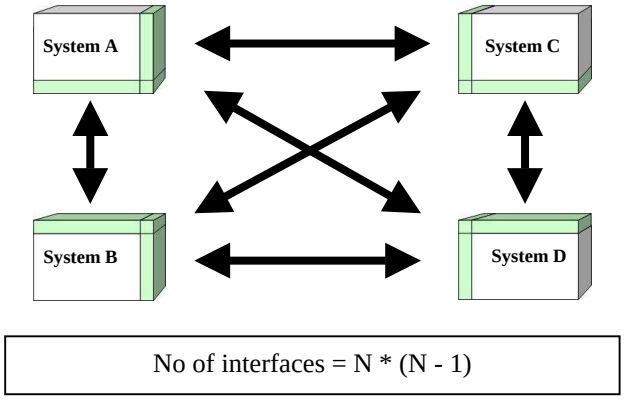

Figure 1: The NxN Problem

Part of the objectives in this exploration is to reduce the problem from a NxN to a N+1 problem as illustrated in Figure 2. The strategy is to integrate various systems through a common web-service interface that provides a common access to the information hub, developed based on C2IEDM. Through this interface, each system that is added to the network will just need to build one single interface to this common web-service interface and the system will be interoperable with the rest of the systems on the network. Thus, this strategy will essentially reduce the number of interfaces required to N+1.

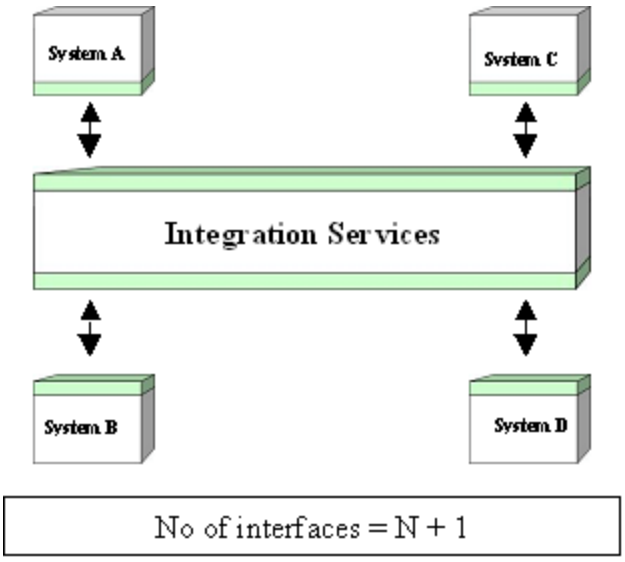

Figure 2: Reduction to a N+1 Problem

The Multilateral Interoperability Programme (MIP) C2IEDM is chosen as the referential data model for this exploration as it supports majority of the entities required for capturing Orbat information. MIP's aim is "to achieve international interoperability of Command and Control Information Systems (C2IS) at all levels from corps to the lowest appropriate level, in order to support combined and joint operations." [2]. Adopting C2IEDM could lead to better interoperability with MIP-compliant C2IS from other nations that are involved in the relief operations. In addition, as C2IEDM is jointly developed by 26 MIP members including many NATO countries, adopting the model would mean tapping on the operational experience of these members in defining the model. As the exploration is evolutionary, the MIP Data Exchange Mechanism (DEM) is slated to be explored in subsequent phases of the project and thus will not be discussed in this paper.

Although C2IEDM is able to capture majority of the Orbat related information stored in current IT and C2 systems, the model needs to be extended with additional dependent entities (eg. Appointment and Person-Course), relevant relationships and additional domain values (national specific), in order to capture all essential information. In this case, Appointment and Person-Course are required, such that the person holding the appropriate appointment and equipped with the correct training is being assigned to tackle different scenarios of the relief operation. Figure 3 shows the extension to the model. These extensions answered to the needs of national requirement on the model, however, it poses a problem for international interoperability, as MIP DEM specifies that all C2IEDM databases using the DEM for data synchronisation must use the same version of the model. Though MIP DEM is not addressed in the current phase of the exploration, an option being considered is to develop a mapping from the national information hub to a standard C2IEDM that is meant for international interoperability.

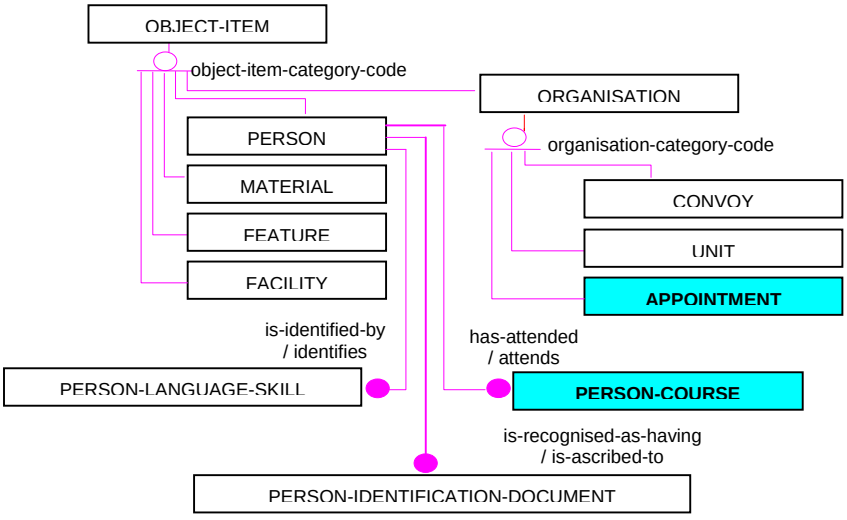

Figure 2: Extension to C2IEDM

Figure 4 shows the mapping between systems that use different data models. A set of mappings is created for each system that uses non-C2IEDM data model. Information

from systems with proprietary data model is mapped to the national information hub, which is based on extended C2IEDM. As the extended model could not be replicated directed with standard C2IEDM, a mapping between the extended model and the standard model is created as well. The data is then replicated from the National Information Hub to the standard C2IEDM through the mapping defined. As can be seen from the diagram, national systems could maintain their international interoperability though they are running on an extended C2IEDM. In addition, this architecture could also shield national systems running on extended C2IEDM from the changes of evolving MIP Blocks[2]. The impact of the evolving MIP blocks on national systems can thus be restricted to the mapping module between the extended model and the standard model, reducing the maintenance required significantly as compared to maintaining and migration National systems as and when a new C2IEDM version is released.

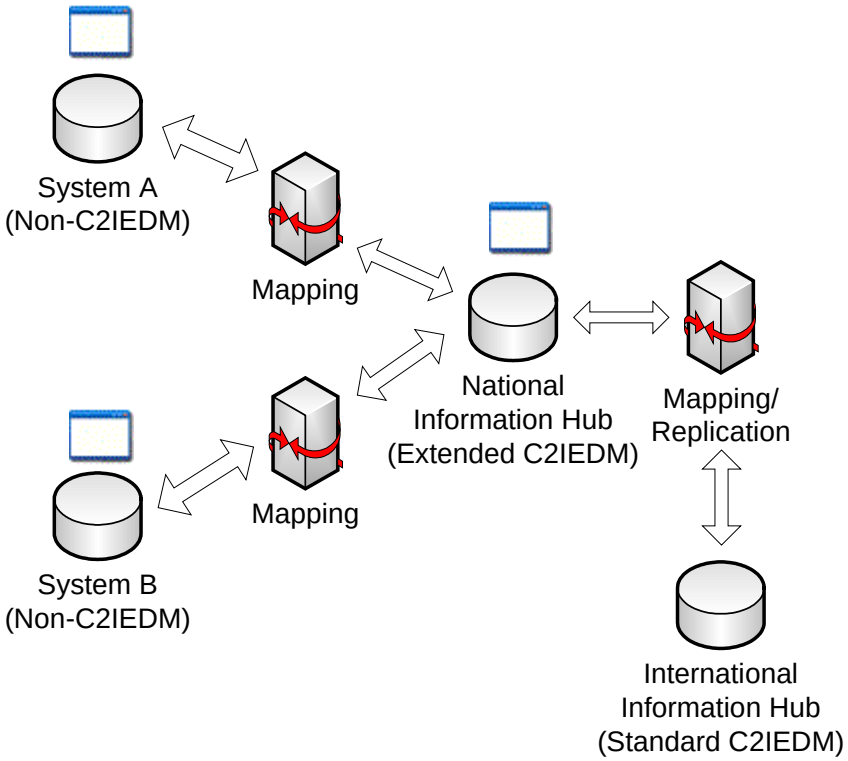

Figure 4: Mapping between Different Data Models

3 Common Interfaces

Dr Michael Schmitt [3] proposed a model for C2IEDM data access in his paper, titled "Integration of the MIP Command and Control Information Exchange Data Model into National Systems". The considerations for using the data access model are:

[2] MIP releases a new 'Block' every three years that remains 'in-service' for two years.

- Maintainability – MIP data model undergoes frequent updates. C2IS that relies on the relational schema of the model has to be adapted with every model update, resulting in poor maintainability.
- Efficiency – C2IEDM is primarily designed for information exchange and is not optimised for fast data access. To improve efficiency, high level data objects should be defined that abstract from the complexity of the data model.
- Correctness – C2IEDM has some potential pitfalls, which can result in erroneous data if used improperly. Common operations should be handled centrally to ensure correctness of the data.

In addition to the above considerations, the following are being considered as well:

- Complexity – The complexity of the model resulting in steep learning curve. The complexity also resulted in the need of complex SQL statements for retrieval of desired data. By building a common interface on top of the model, the complexity of the model could be shielded from business application developers by leveraging on the knowledge of the current team.
- Accessibility – Building on Dr Michael's model, a common interface using XML based web services was implemented. Using the Service Oriented Architecture (SOA) framework [4], the interface implemented is loosely coupled and could be reuse by other applications or services. The services could be accessed by distributed systems through discovery and consumption of the services developed. In addition, the layer of web services also ensures the integrity and consistency of data during retrieval and updates to the model by enforcing business rules mandated in MIP documentation.

Figure 5 shows the architecture for the interface. As web services are generally considered as a pull mechanism, a push mechanism using Publish & Subscribe (P&S) mechanism was incorporated for pushing updates of units and personnel to systems that have subscribed to the topic of interest. XML based messages with schemas that reuses C2IEDM entities were adopted for ease of interpretation by the receiving systems.

4 The Prototype

A force management system prototype was developed to validate the concept of integrating IT and C2 systems through C2IEDM and the web service interface. Force management was chosen to assess on the ability of this concept in supporting the requirement of forming a disaster relief team quickly and to account and track the resources deployed in the operation. A set of force management web services was developed, which act as the application interface to the model. In addition a force management front-end was developed to demonstrate the inter-operability of new and existing systems through the interface.

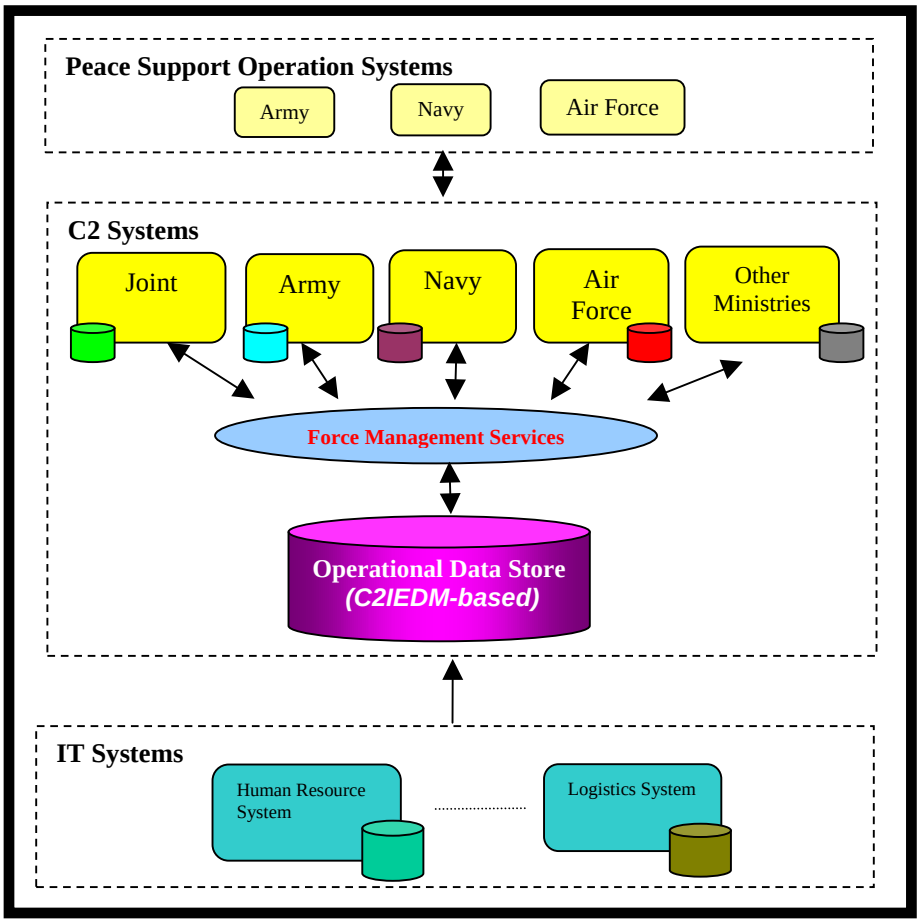

Figure 3: System Architecture

The US Default Operational Organisation (DOO) concept [5] was adopted, whereby a stable default organisation structure is created and maintained such that relief teams could be easily created prior to operations by re-linking the relations between the organisations in the DOO. In the prototype, information from human resource systems is mapped and transferred into the model. Additional conceptual organisations, used primarily during operations for aggregation and reporting of sub-units statuses, were created subsequently using information from C2 systems, to form the DOO.

A sample DOO (Orbat Template) is shown on the left frame of the prototype's User Interface (UI) in Figure 6. The middle frame shows the organisation structure of the relief team (TF) that is created by "dragging" the relevant organisations, appointments and personnel from the DOO. This demonstrated the ability of the prototype to create a disaster relief team rapidly. At the back of the UI, such actions performed by users are interpreted to various web service calls to the interface layer for retrieval and updates to the ODS.

The statuses of the organisations involved in the operations are simulated by a C2 system by submitting reports through the P&S mechanism. An existing system was identified to demonstrate the interoperability through the interface by building a web service client that consumes the set of force management services and display organisations' statuses

on a map display. The advantage of the interface was clearly visible as it took the development team minimal effort of just over 3 weeks to be inter-operable with existing IT and C2 systems. The existing system brought in just need to develop the additional interface to the model, instead of building multiple interfaces to the IT and C2 systems, thus reducing the time and effort significantly.

The right frame of the UI in Figure 6 shows the statuses of personnel and organisations, while the bottom frame of the UI shows the personnel details mapped from the human resource systems. Figure 7 shows the UI of the existing system displaying the location statuses of relevant units retrieved through the FMS service.

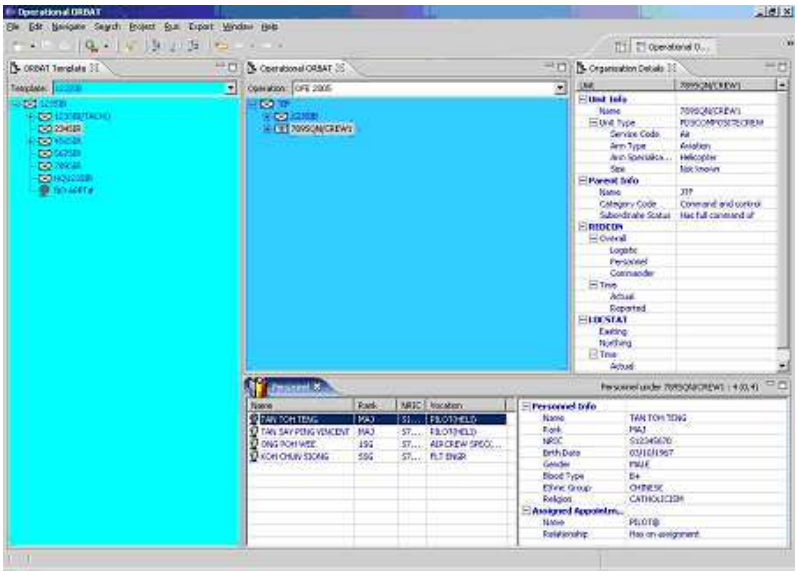

Figure 6: Force Management User Interface

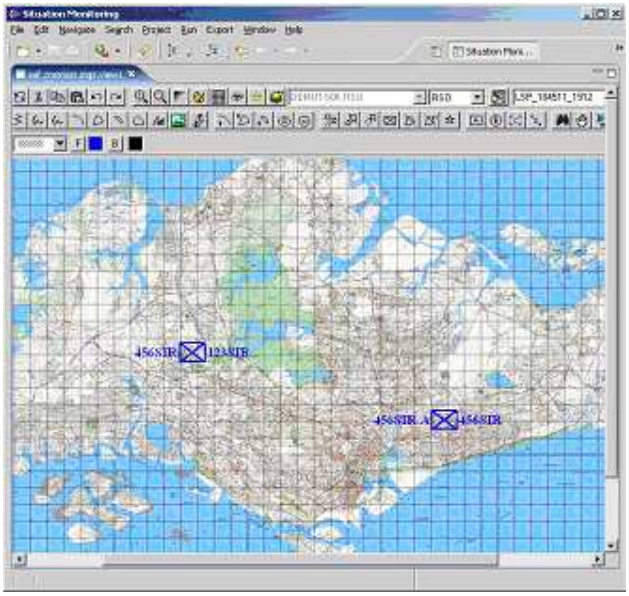

Figure 7: Map Interface for Situation Awareness

5 Lessons Learnt

During the exploration, several issues were encountered, which we shall discuss in this section. The issues are:

- *C2IEDM extensions*

  As discussed earlier, the model was extended to cater for national information requirements. The key principles of C2IEDM extensions were followed:

  i. The basic C2IEDM data representations are not changed, and
  ii. Extensions are always done in the least obtrusive manner, i.e.,
     (a) new information is modelled by new attribute values first. If this is not sufficient,
     (b) the category and subcategory codes are extended in order to generate new subtypes of existing concepts. If, and only if this is not sufficient,
     (c) new concepts and associations are introduced.

  However, some interoperability problems could still exist even if the principles were followed closely. Two main cases where problems will arise is as follow:

  i. When the model is extended with new attribute value/category, other nation's C2IEDM without similar extensions will encounter problem while interpreting the new attribute/category introduced.

     One way to overcome this is to maintain the standard attribute values and category codes, while creating extended tables which will be referenced by national systems when they encountered values such as 'not specified' or 'not otherwise specified'. For instance, in Figure 3, when national system encounter an organisation with the organisation-category-code specified as 'not otherwise specified', it will lookup the 'Appointment' entity for detail information. For cases where there are several new subcategories to be introduced, we could branch 'not otherwise specified' category in the 'organisation' entity into another whole set of subcategories and their relevant entities which are visible only to national systems. For other nation's C2IEDM, they will only know that the particular organisation in concern is of 'not otherwise specified' class.

  ii. Introduction of additional attribute to existing entity will cause interoperability problem as DEM requires all C2IEDM involve in the replication to be of the same version.

     Another approach under consideration to overcome this is to maintain the standard C2IEDM entity as it is while creating new

national entity that have a primary key which references to the entity requiring extension. For instance, the PERSON-COURSE entity in Figure 3 is a new national entity, which references to PERSON entity. Any additional information that needs to be captured can then be included in the new entity. As there are no changes to PERSON entity and the existence of new entity/relationship is transparent to other nation's C2IEDM, the interoperability problem can be avoided while still addressing national information requirements.

- *Performance*

  During the development of the prototype, there was performance issues when using web services and the model. Though the prototype's focus is not on performance optimisation, a brief study was performed to look into the problems and the following were identified:

  i. Synchronous services were used for retrieving relatively large amount of information initially, causing a sluggish front-end. To overcome this, synchronise web services was invoked for fast retrieval of high level organisations while asynchronous web services were invoked in the back-end for retrieval of detail information concurrently. This provides a responsive front-end with details being populated subsequently from asynchronous web services returns.

  ii. Due to the highly normalised design of the model, the SQL queries are complex and computational intensive, resulting in slow performance. A proposal is to create accelerated tables for keeping frequently accessed information. Alternatively, the web services layer could be implemented on top of the data access stack proposed by Dr Michael [3].

  iii. The problem with slow performance of complex SQL queries is compounded by the amount of records to be kept in C2IEDM that grows overtime due to the basic principle that no data should be deleted from the model. To keep the amount of records in the model in check, proper archiving of the model will need to be put in place should the nation intends to use the model for continuous operation. Issues such as whether the IDs should be recycled when existing information is archived will need to be addressed.

- *Mapping*

  The other major issue encountered is the mapping between data model in existing systems and C2IEDM. As the data model for existing systems were designed to meet individual system's needs, the design concepts for their models deviate from each other as well as C2IEDM. This posed a challenging mapping issue, often require manual intervention to ensure that the mapping is complete and correct. In

addition, customised mapping script will need to be written to complement the standard mapping functions provided by Commercial Off The Shelf (COTS) mapping tools. It is thus recommended that the design of new systems should factor in the support for a complete mapping to C2IEDM so as to avoid such issues in the future.

6 Summary and Conclusions

In this paper, we have discussed on the exploration of integrating new/existing IT and C2 systems through a common interface build on top of a C2IEDM based Information Hub. We have demonstrated the potential of such interface through the force management prototype developed during the exploration. Although the current work did not look into MIP DEM, we do not foresee much difficulty incorporating DEM for inter-operability with other nations. We have discussed key lessons learnt from the exploration and proposed approaches to overcome several challenges.

7 References

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   http://www.dodccrp.org/publications/pdf/Chamberlain_Default.pdf

8 Biographies

MR Andy Ong is a project manager in the Battlefield Command and Control Programme in Defence Science & Technology Agency. Mr Andy has a Masters of Technology, majoring in Knowledge Engineering from the National University of Singapore and a Bachelor of Engineering (Electrical & Electronic) from the Nanyang Technological University. He has more than 7 years of experience in the development and management of Army command and control (C2) information systems.

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MR LAI YING CHEUNG is the Division Manager of the Joint/Army Tactical C2 Solutions Division in Defence Science & Technology Agency. He graduated from the National University of Singapore, majoring in Communication Engineering. Mr Lai has more 20 years experience in the area of communication system design, development and project management. His work experience includes communication system architecture and command and control (C2) information system. He plays an active role in the development of the Army Knowledge Enterprise System.

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June 2006, San Diego

Leveraging on C2IEDM for Enhancing Systems Interoperability

Andy Ong, Lim Yoon Min, Lai Ying Cheung

DSTA

Scope of Presentation

- Overview
- The Exploration
- Lessons Learnt
- Conclusions

Overview

Deployment of Personnel and Resources as at 7 Jan 2005 (0830hrs)

Total Personnel: 1098

Sources: MFA, MINDEF, SCDF, SPF, MOH








Chennai (Total: 5 personnel)
MFA: 5

Dhaka (Total:3 personnel)
MFA: 3

Phuket (Total: 186 personnel)
MINDEF: 45
SCDF: 80
MFA: 13
Inter-Ministry (led by SPF): 48
SAF/SCDF resources: 2xSP, 2xlorries
• Airlifts of medical and relief supplies

Colombo (Total: 3 personnel)
MFA: 3
•Airlift of medical and relief supplies
•2nd airlift of medical and relief supplies underway

Indonesia (901 personnel)
MINDEF: 847
SCDF: 27
MFA: 3
MOH: 24
SAF resources: 6xCH47, 2xSP, 2xLST, 2xSCDF lorries
•Airlifts of medical and relief supplies
•Deployment of 210x10ltr bags of potable water

Maldives
•Airlifts of 600x10ltr bags of potable water
•Shipment of water desalination plant

Source: http://www1.nvpc.org.sg/tsunami/_resources/library/1_MFAPresentation.pdf

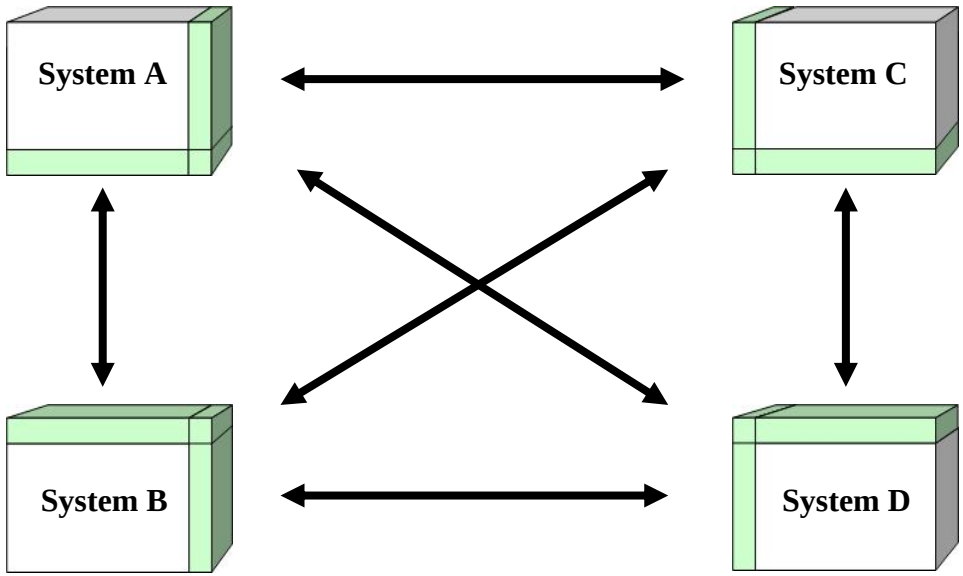
Exploration Objectives

- Explore on a system architecture for:
  - Enabling rapid pooling of resources from different agencies together
  - Maintaining full visibility of status of the resources deployed

- Competency build-up on C2IEDM

Current Situation

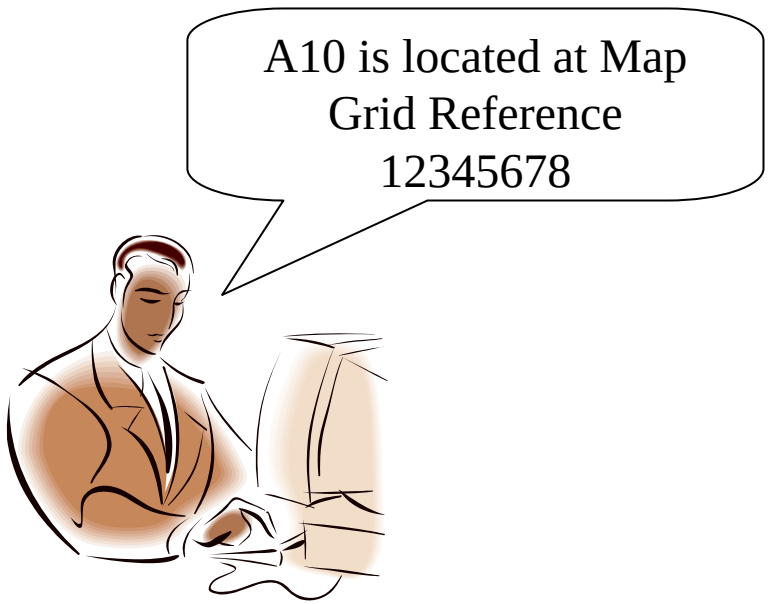
- Information residing in different systems

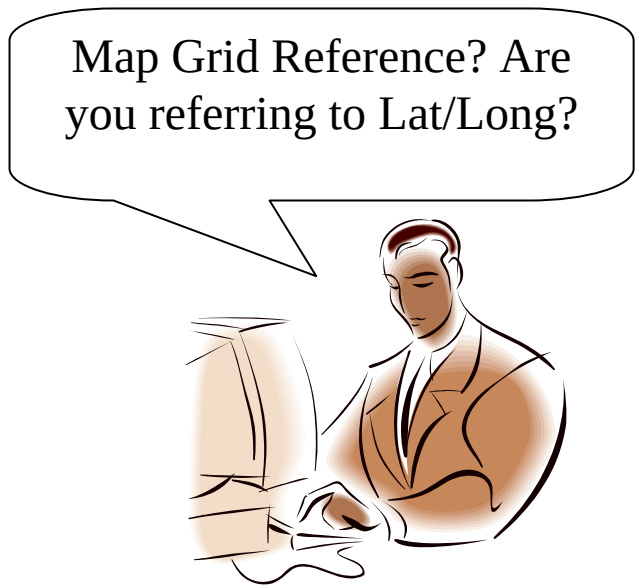


No of interfaces = N * (N - 1)

Current Situation

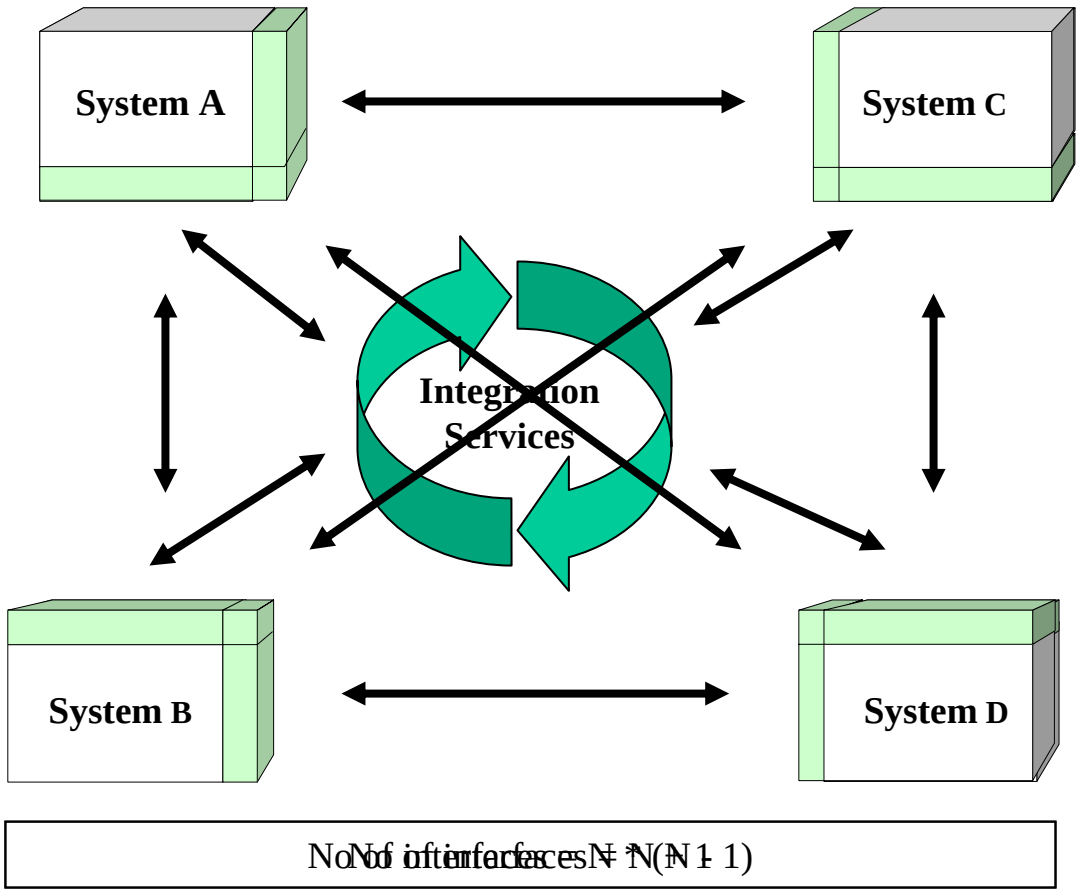
- Common language?





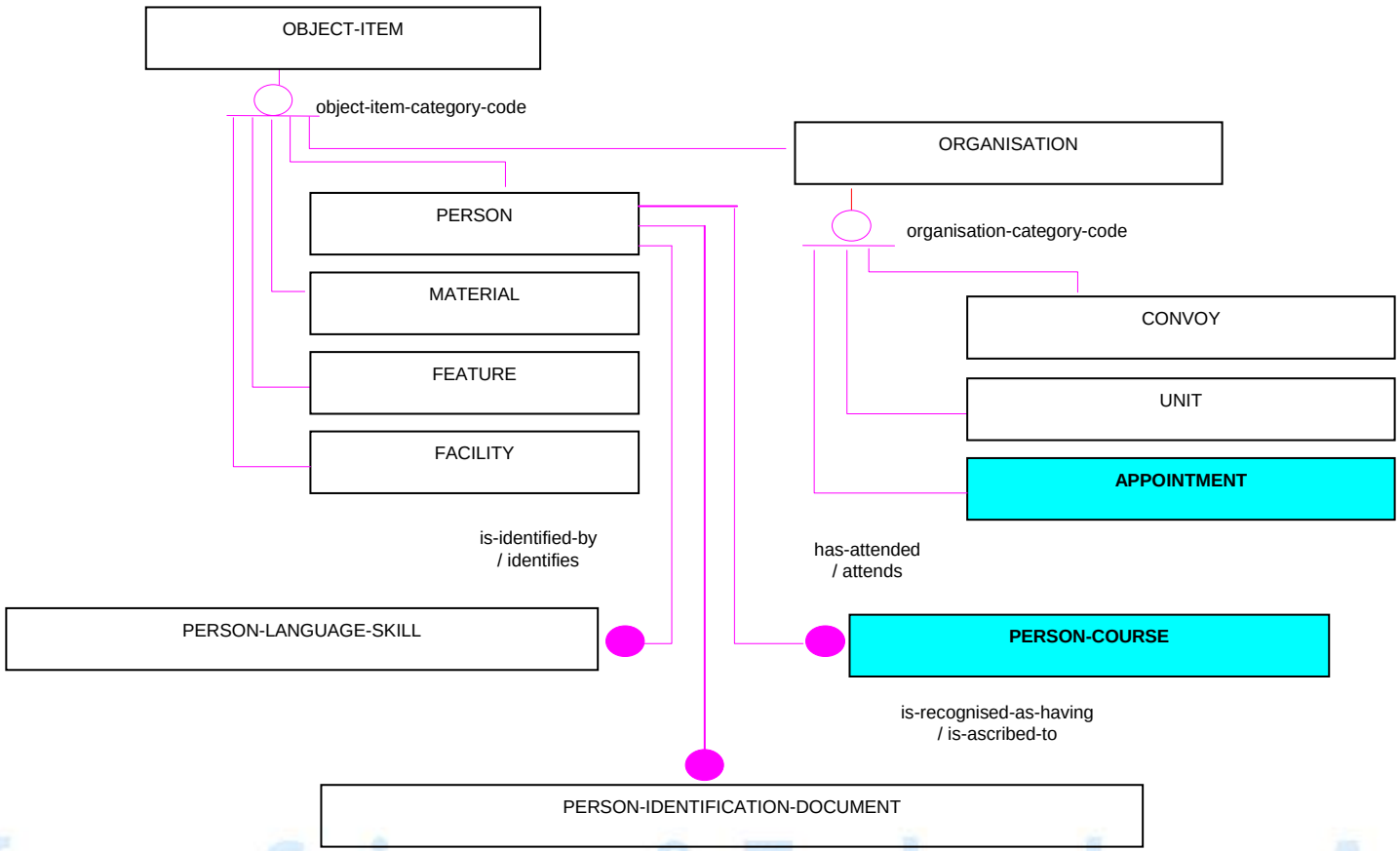
Common Interface

- Common Interface for better interoperability



Common Language and Model

- Common language – C2IEDM



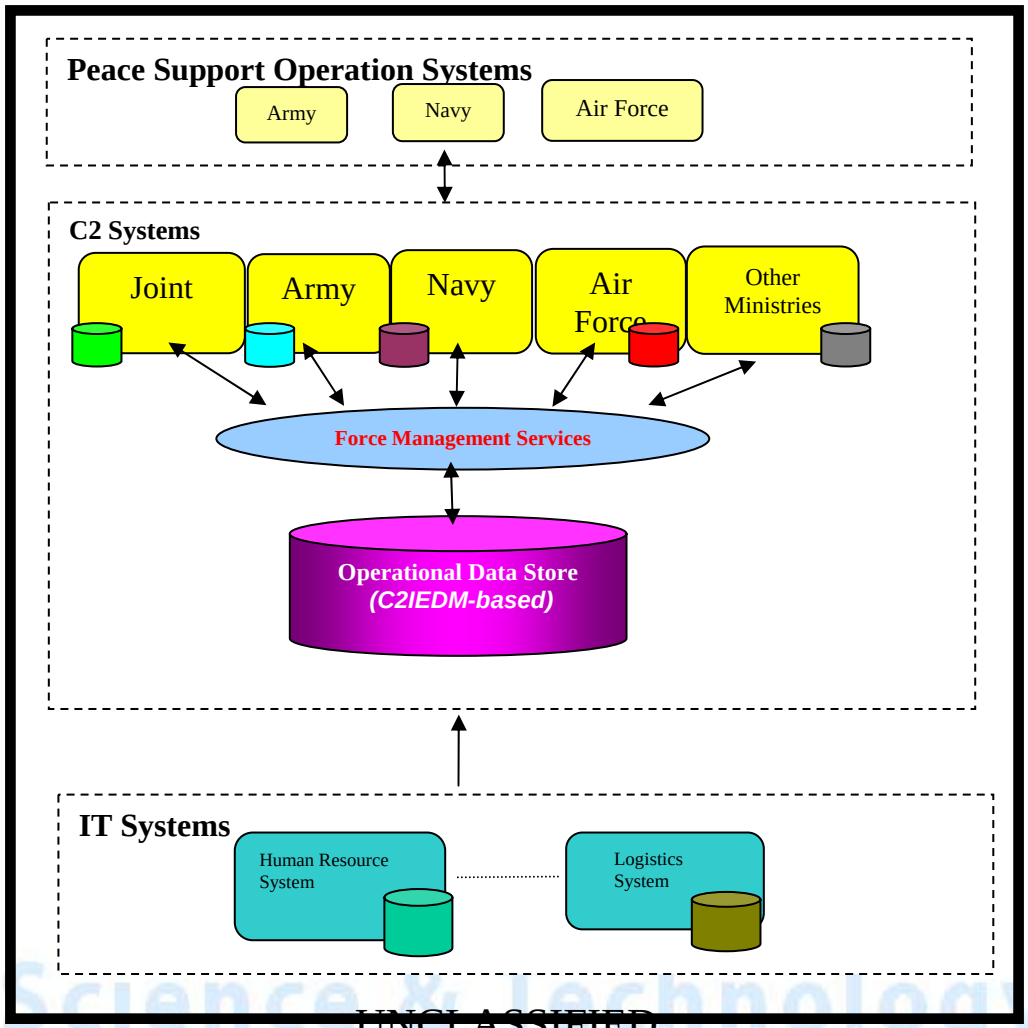
The Exploration

- Start small using HR and two C2 systems as a POC
- Force Management System for creation of organisation structure and monitoring of task forces
- Adopted US concept of Default Operational Organisation[1] for rapid creation of operational force structure
- Use C2IEDM as the operational data store
- Use XML web services for building common interface

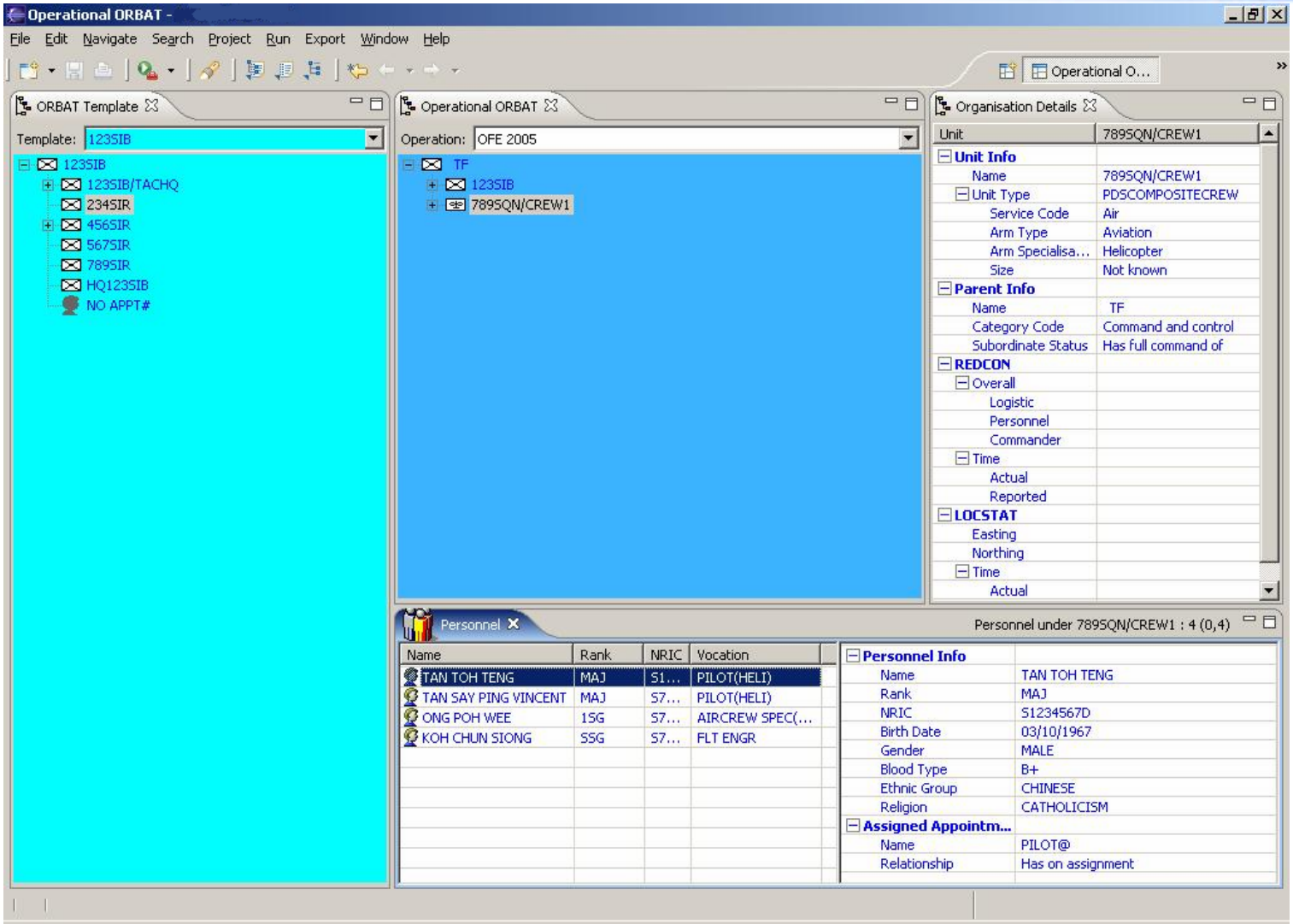
[1]Default Operational Representations of Military Organisations, Dr Sam Chambelain, Information Science & Technology Directorate, US Army Research Laboratory, Feb 2000.

The Exploration

- System Architecture



Front-end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Arm Type Aviation
Arm Specialisa... Helicopter
Size Not known
Parent Info
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Category Code Command and control
Subordinate Status Has full command of
REDCON
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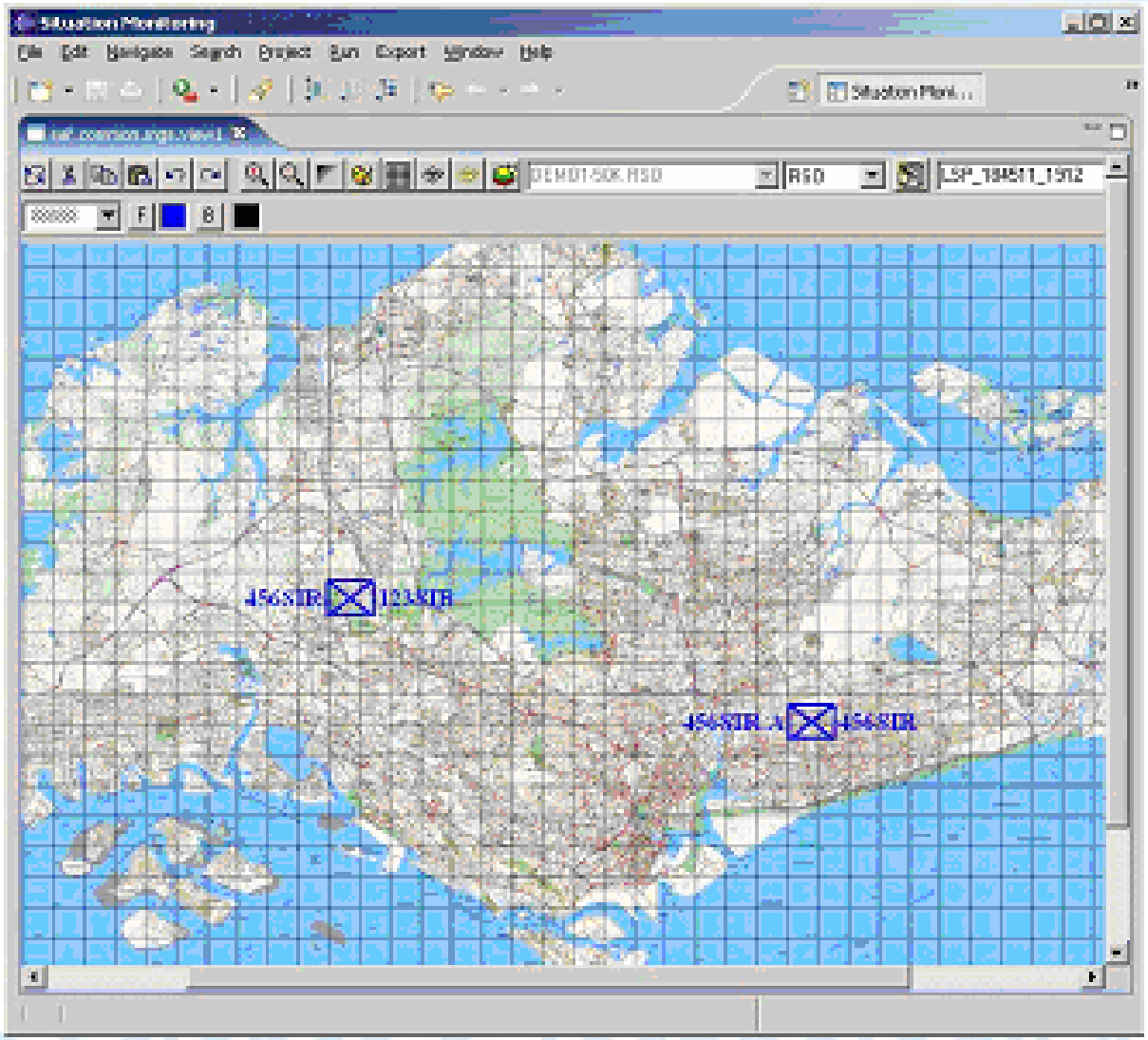
Rank MAJ
NRIC S1234567D
Birth Date 03/10/1967
Gender MALE
Blood Type B+
Ethnic Group CHINESE
Religion CATHOLICISM
Assigned Appointm...
Name PILOT@
Relationship Has on assignment

Front-end


Mission Monitoring
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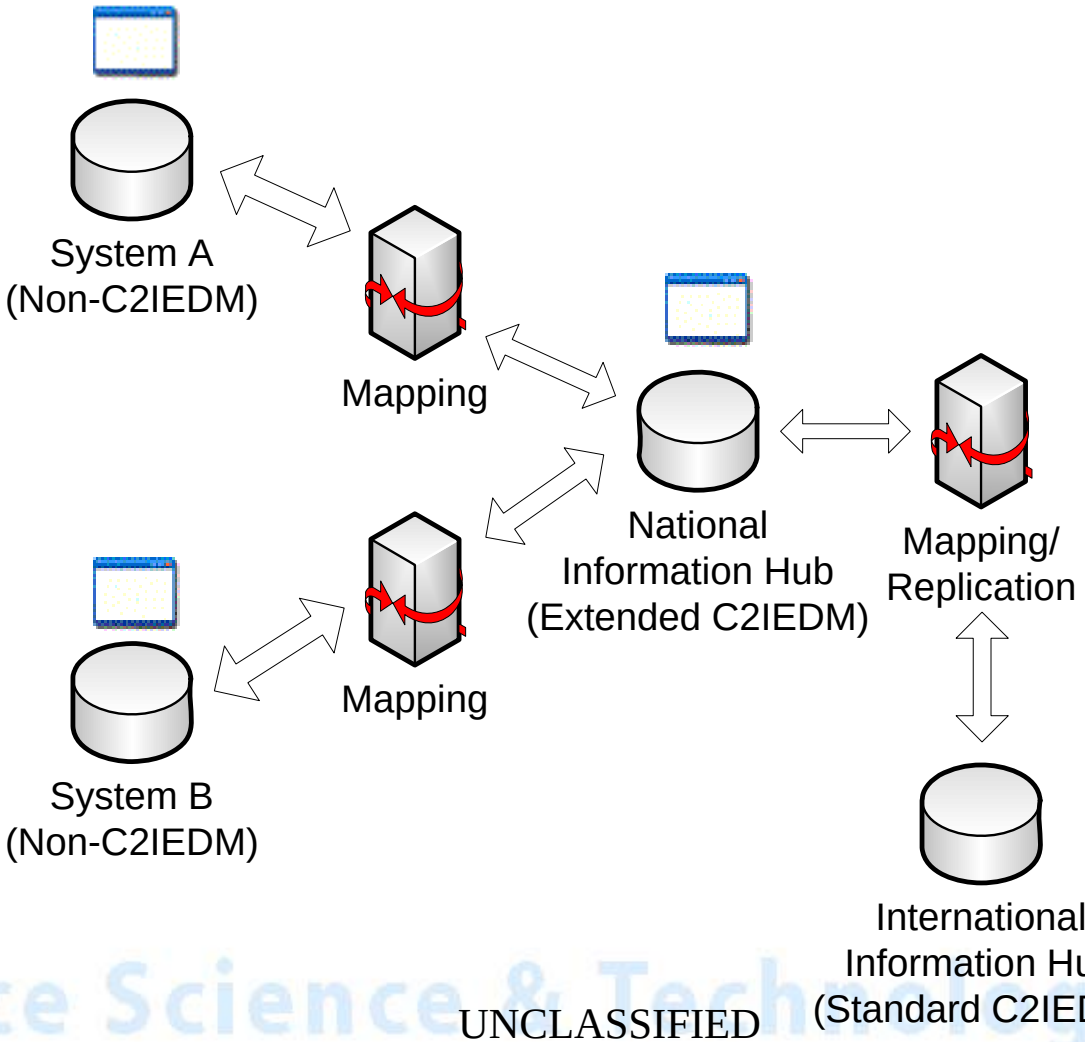
Lessons Learnt

- C2IEDM Extensions
  - Extensions to include appointments and person-course
  - Maintain existing category codes / attribute values. National system to reference to extended tables when values such as ‘NKN’ or ‘NOS’ are encountered
  - Maintain existing entity attributes and create additional entity that links to the existing entity via Foreign Key

Lessons Learnt

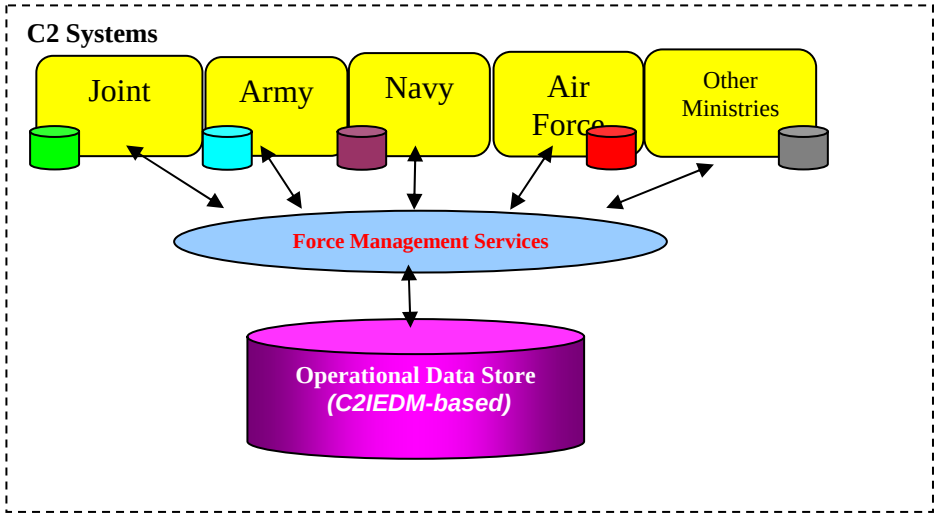
- Evolving C2IEDM MIP Blocks



Lessons Learnt

- Mapping
  - Use C2IEDM for new systems, if possible
  - Design new systems' data model factoring the necessary mappings to C2IEDM

Lessons Learnt



- Using interface layer:
  - To isolate model complexity
  - To buffer impact to applications as MIP releases new versions of the models

Lessons Learnt

- Performance
  - Use synchronous services for retrieval of brief information while invoking asynchronous services for retrieving details
  - Create accelerated tables/views for frequently accessed information
  - Archival of old data, recycle of keys?

Conclusions

- Extensions to C2IEDM must be done with care. Consider the suggestions provided in this presentation to avoid interoperability issues
- Use interim layers to buffer the model's complexity and version changes to the model
- Design your data model with mapping to C2IEDM in mind
- Strategy for archival and key management needs to be derived

Q & A

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Thank You